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ORIGINAL ARTICLE

Usefulness of preoperative CT colonography for colon cancer

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Summary *Background:* Computed tomographic colonography (CTC) is reported to be feasible for screening of colorectal polyps; however, its efficacy in preoperative workup remains unknown. This study was done to define our CTC methodology and assess CTC's potential for preoperative examination in patients with colon cancer.
Methods: A total of 86 colon cancer patients underwent CTC prior to laparoscopic colectomy in our department from February 2014 to November 2015. The location of primary colon cancer determined by CTC was compared with that confirmed during the surgery. CTC was performed just after preoperative colonoscopy; for a small colon cancer, we performed clipping during colonoscopy to enhance CTC detectability. We classified wall deformities and compared them with the pathological T stage.
Results: CTC accurately located all 87 primary colon cancers prior to surgery. No patient experienced complications associated with CTC. The deformity classification correlated significantly with the pathological T stage ($p < 0.001$, Kruskal–Wallis nonparametric tests). CTC provided reconstructed images depicting the feeding artery of the primary colon cancer; feeding artery information obtained by CTC facilitated precise lymph node dissection.

Conflicts of interest: None.

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Conclusion: CTC appears to be a feasible and useful preoperative examination modality for colon cancer treatment.

1. Introduction

Colorectal cancer is a serious health problem worldwide because of its high frequency and mortality.[1,2] Despite recent progress in chemotherapy, surgical resection is the only curative therapy for colorectal cancer.

Computed tomographic colonography (CTC) was first performed by Vining et al[3] in 1994 at Wake Forest University using volumetric computed tomography (CT) data produced by helical CT scanning. The development of multislice CT and the improvement of workstations and software have facilitated the clinical applications of CTC[4] as alternatives to colonoscopy or double-contrast barium enema (DCBE) for the screening and detection of colorectal polyps.

Recently, laparoscopic surgery has become common, and in randomized trials it has shown results comparable to those of open surgery.[5] In laparoscopic colectomy, because palpation during the procedure is not feasible, accurate preoperative localization is crucial, especially that of lesions that are not apparent on the serosal surface. Therefore, knowing the exact location of the tumor is of utmost importance, particularly for effective colectomy and lymph node dissection. Several studies have evaluated the usefulness of CTC in preoperative evaluation. Nagata et al[6] reported that the detectability of colonic lesions by CT enema was 97% (319/328). CTC has also been reported to be a valuable tool for evaluating the proximal colon in incomplete colonoscopy caused by stenosis in large colon cancer.[7,8] These studies, however, do not address the problems of locating lesions undetected by CTC.

In this study, we describe our approach to the detection and localization of small preoperative cancers and evaluate its potential role in the preoperative examination of patients with colon cancer.

2. Materials and methods

2.1. Patients

We reviewed our registry from February 2014 to November 2015. Eighty-six colon cancer patients underwent preoperative CTC and laparoscopic colectomy with lymph node dissection. We had just begun to perform CTC in February 2014 and applied CTC only to colon cancer patients; patients with rectal cancer were therefore excluded from this study. Patients with obstructions were also excluded. We obtained written informed consent concerning CTC prior to the examination from all patients.

2.2. CTC technique

First, all patients underwent 2 L of polyethylene glycol lavage as a full preparation prior to total colonoscopy, which was performed by experienced gastroenterologists, immediately followed by CTC. If a small cancer ($<$ 10 mm) was detected in colonoscopy, then metallic clips (HX-610-090; Olympus, Tokyo, Japan) were endoscopically applied to the cancer site with a roticulator clip-fixing device (HX-110UR; Olympus) to ensure CTC locatability of small cancers.

The patient was placed on the multislice CT scanner (Aquilion One Vision Edition or Aquilion PRIME; Toshiba Medical Systems, Tochigi, Japan) in the left lateral decubitus position. Thereafter, carbon dioxide gas was infused through a balloon catheter placed in the rectum with an automated insufflation device (PROTOCO2L; EIDIA, Tokyo, Japan) equipped with a pressure monitor. The patient was rotated to the supine position 1 minute after the start of insufflation to transfer the gas into the transverse colon. When the infusion volume reached 2 L or more and the intracolonic pressure was stable at 18 $\pm$ 2 mmHg, a CT scanogram was done to confirm that sufficient colonic expansion was obtained. Then, abdominopelvic CT scans were performed. The patient was subsequently rolled over to the prone position while the gas insufflation was continued. When the enteral pressure stabilized at 18 $\pm$ 2 mmHg and sufficient colonic expansion was confirmed by another scanogram, a CT scan covering the entire colon and rectum was performed. Thin-slice CT images were reconstructed from the volumetric CT data and then transferred to a dedicated workstation (Advantage Workstation; GE Healthcare Japan, Tokyo, Japan), which allowed visualization of two-dimensional axial and multiplanar reformatted images, three-dimensional endoluminal surface-shaded volume rendering images, and DCBE-like images (Figure 1). Radiologists blind to the results of colonoscopy interpreted the CTC studies.

As a preoperative examination of cancers, we performed CT scans after injecting contrast media unless contraindications were present at the same time as CTC. Three-dimensional images of the feeding artery of the primary cancer were reconstructed to ensure safe and adequate lymph node dissection.

2.3. Data analysis

We reviewed the clinicopathological data—sex, age, characteristics of cancers, and complications related to CTC. The cancers' location, size, morphological type, grade of invasion, and differentiation determined pathologically were reviewed. The morphological type was classified in accordance with the Paris—Japanese classification[9]: Type 0,

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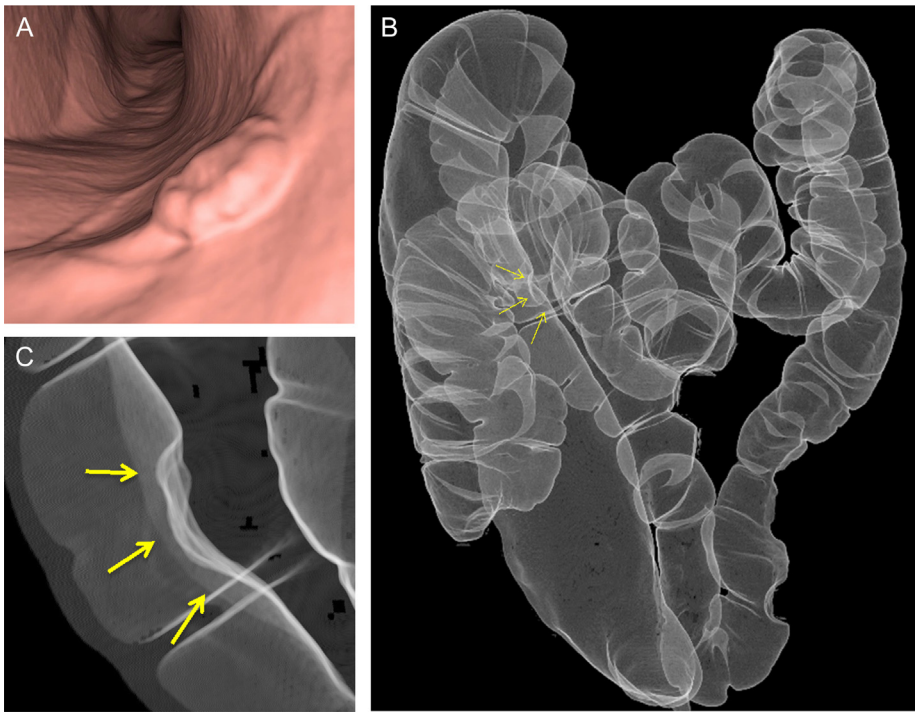

Figure 1 CTC images of a patient with a long sigmoid colon. Both three-dimensional endoluminal surface-shaded volume rendering images and DCBE-like images detected sigmoid colon cancer (20 mm, type 2, pT2). (A) A three-dimensional endoluminal surface-shaded volume rendering image. (B) A DCBE-like view of the entire colon; the location of the cancer is indicated by the yellow arrow. (C) A magnified DCBE-like view of the sigmoid colon cancer. CTC = computed tomographic colonography; DCBE = double-contrast barium enema.

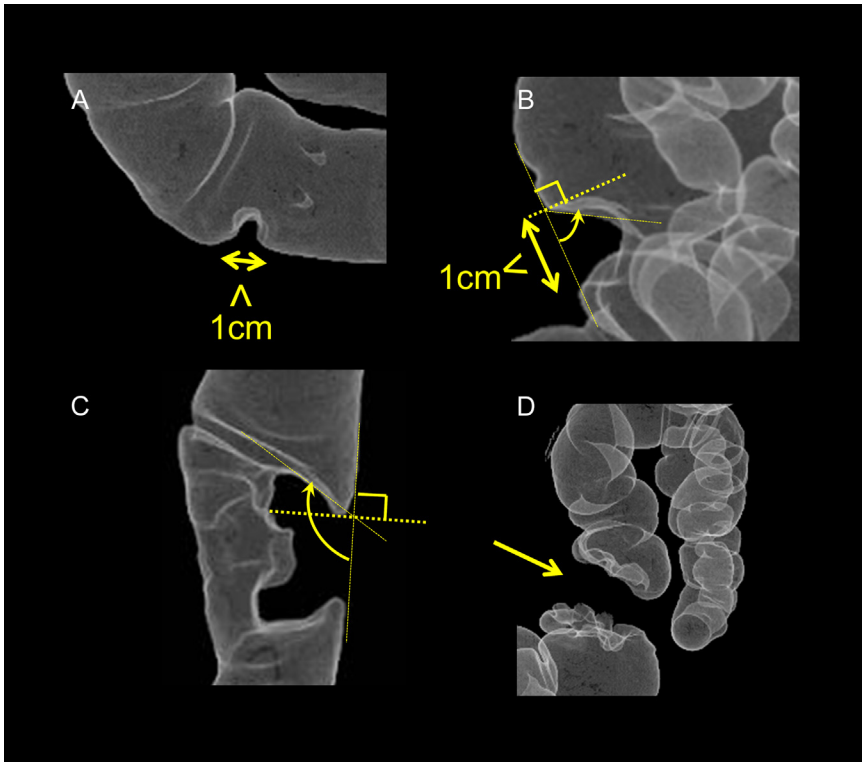

Figure 2 (A) The arrow shows a slight deformity (SL). In SL, the length of the deformity is less than 1 cm. (B) The arrow shows a mild deformity (MLD). In MLD, the length of the deformity is equal to or greater than 1 cm, and the slope is gradual and the angle is less than 90°. (C) The arrow shows a moderate deformity (MOD). In MOD, the slope is steep and the angle is greater than or equal to 90°. (D) The arrow shows a severe deformity (SV). Only an apple-core-like deformity is classified as SV.

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superficial polypoid type (Is, sessile; Ip, pedunculated; Isp, mixed) and superficial mixed type (IIa + IIc: slightly elevated and depressed); Type 1 (polypoid carcinomas, usually attached on a wide base); Type 2 (ulcerated carcinomas with sharply demarcated and raised margins); Type 3 (ulcerated, infiltrating carcinomas without definite limits); and Type 4 (nonulcerated, diffusely infiltrating carcinomas).

The primary colon cancer's detectability was evaluated. The location of the cancer confirmed during surgery was used as the control, and the finding from CTC was regarded as the experimental group.

According to the classification method previously reported by Nagata et al,[6] we classified the wall deformity into four groups: slight deformity (SL); mild deformity (MLD); moderate deformity (MOD); and severe deformity (SV). In the case of SL, the length of the deformity was less than 1 cm (Figure 2A). In MLD, MOD, and SV, the length of the deformity was equal to or greater than 1 cm. The difference between MLD and MOD lay in the steepness of the slope of the deformed outlined intestinal tract. In MLD, the slope was rather gradual and the angle was less than 90° (Figure 2B). In MOD, the slope was steep and the angle was greater than or equal to 90° (Figure 2C). Only apple-core-like deformity was classified as SV (Figure 2D).

We compared the classification of deformity with the pathological T stage using the Union for International Cancer Control (UICC) classification. The Kruskal–Wallis nonparametric test was performed and Cramér's *V* was calculated with R 3.1.3.

3. Results

3.1. Clinicopathological characteristics of patients and cancers

Fifty patients were male and 36 were female; their median age (range) was 67 (32–89) years. The cancer characteristics and detectability are shown in Table 1. The regional distribution of cancers determined during surgery was cecum ($n = 7$), ascending colon ($n = 13$), transverse colon ($n = 9$), descending colon ($n = 8$), sigmoid colon ($n = 43$), and rectosigmoid colon ($n = 7$). The cancer size was smaller than 10 mm in one patient, 10–20 mm in nine, and greater than 20 mm in 77. The invasion depth of the primary cancer using the UICC criteria revealed in pathological examination was Tis (carcinoma *in situ*) in three patients, T1 in eight, T2 in 11, T3 in 48, and T4 in 17. Lymph node metastasis was negative in 53 patients and positive in 33. Distant metastasis was negative in 85 patients and positive in one. Forty cancers were well-differentiated adenocarcinoma, 40 were moderately differentiated, and seven were poorly differentiated. All patients completed CTC without complications.

3.2. Successful location of the primary cancer with CTC

Eighty-six cancers out of 87 were detected with CTC (sensitivity: 98.9%). Figure 3 shows the sole cancer that was not detected with CTC. It was 8 mm in size; therefore clips were applied endoscopically, and it was located with the aid of the metallic clips. As mentioned above, metallic clips were endoscopically applied to small cancers (<10 mm) to ensure CTC would locate them.

The location of the 87 cancers depicted by CTC was consistent with that confirmed intraoperatively, and this enabled us to perform the operation without changing the position of the port.

3.3. Estimation of the depth of cancer invasion with CTC

The classification of deformity and the pathological T stage (depth of cancer invasion as the UICC criteria) of the 86 detected cancers are compared in Table 2, where a definite correlation between them is observed: as the depth of invasion increased, the grade of the deformity became more severe (SL < MLD < MOD < SV), and the correlation between classification of deformity and pathological T stage was significant ($p < 0.001$, Kruskal–Wallis nonparametric test); Cramér's *V* was 0.76.

Table 1 Cancer characteristics and detectability.

Category	Number of lesions ($n = 87$)	Number of detected lesions by CTC without clipping ($n = 86$)
Location of cancer		
Cecum	7	7 (100%)
Ascending colon	13	12 (92.3%)
Transverse colon	9	9 (100%)
Descending colon	8	8 (100%)
Sigmoid colon	43	43 (100%)
Rectosigmoid colon	7	7 (100%)
Size of cancer (mm)		
< 10	1	0 (0%)
10–20	9	9 (100%)
20–30	24	24 (100%)
30–40	20	20 (100%)
> 40	33	33 (100%)
Morphological type		
0-Is	2	2 (100%)
0-Isp	2	2 (100%)
0-Ip	2	2 (100%)
0-IIa + IIc	4	3 (75%)
1	9	9 (100%)
2	68	68 (100%)
Differentiation		
Well	40	39 (97.5%)
Moderately	40	40 (100%)
Poorly	7	7 (100%)
Invasion depth		
pTis	3	2 (66.7%)
pT1	8	8 (100%)
pT2	11	11 (100%)
pT3	48	48 (100%)
pT4	17	17 (100%)

IIa + IIc = slightly elevated and depressed; Ip = pedunculated; Is = sessile; Isp = sessile and pedunculated; Tis = carcinoma *in situ*.

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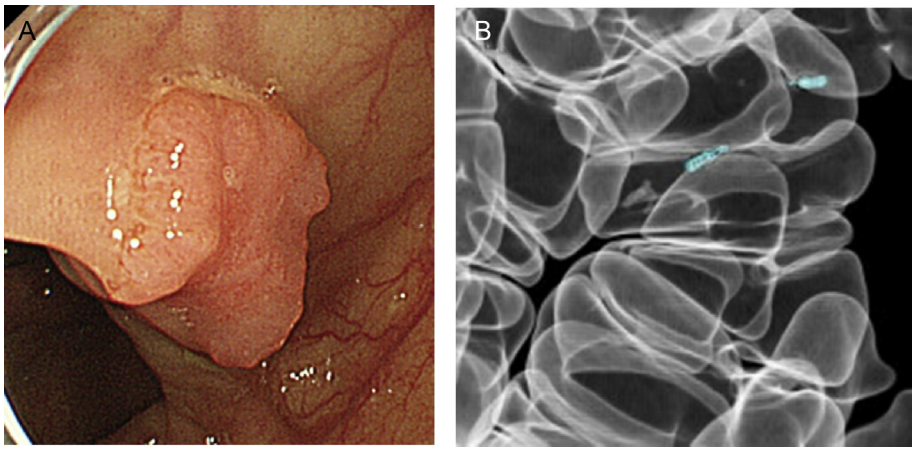

Figure 3 (A) A conventional endoluminal image of a small ascending colon cancer (8 mm, 0-IIa + IIc, pTis) undetected with CTC. (B) A DCBE-like view of the same cancer with two metallic clips. CTC = computed tomographic colonography; DCBE = double-contrast barium enema.

Table 2 Comparison between classification of deformity and pathological T stage (depth of cancer invasion).

	pTis/pT1	pT2	pT3	pT4
SL	7	0	0	0
MLD	3	10	0	0
MOD	0	1	44	7
SV	0	0	4	10

MLD = mild deformity; MOD = moderate deformity; SL = slight deformity; SV = severe deformity; Tis = carcinoma *in situ*.

3.4. Depiction of the feeding artery with CTC

A DCBE-like view of a descending colon cancer together with the reconstructed image of the feeding artery is shown in Figure 4.

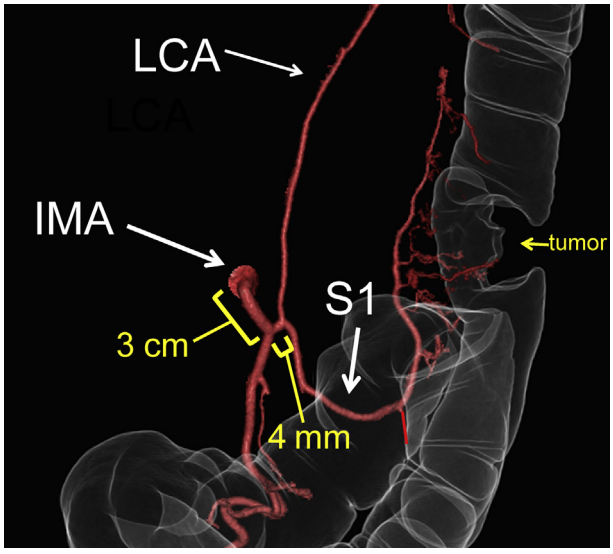

Figure 4 A DCBE-like view of a descending colon cancer together with a reconstructed image of the feeding artery. DCBE = double-contrast barium enema; IMA = inferior mesenteric artery; LCA = left colic artery; S1 = first sigmoid colon artery.

4. Discussion

This study was performed to review our experience with CTC in a series of preoperative examinations and to evaluate the detectability of primary colon cancer and the correlation between deformity and T stage.

CTC accurately located 86 of 87 primary colon cancers without clipping. Together with clipping one small lesion, we succeeded in locating all (87/87) colon cancers with CTC. Therefore, we think clipping should be considered for the detection of small cancers (< 10 mm).

No patient experienced complications associated with CTC. CTC also provided reconstructed images depicting the feeding artery of primary colon cancers, facilitating the performance of safe and precise lymph node dissections.

Endoscopic localization of colon cancers can be challenging because anatomical landmarks are not readily apparent at colonoscopy, and often only the distance from the anal verge is recorded. The endoscopist can also be confounded by the presence of a redundant colon or anatomic variants. As recent studies have shown, colonoscopy has only suboptimal accuracy in locating the tumor: in approximately 11% of cases, locations are incorrect.[10] In 0.9% of patients, inaccurate endoscopic location led to an intraoperative colonoscopy and in 0.3–0.5% of patients, scheduled laparoscopic surgery became open surgery or required an extended resection.[11,12] Thus, colonoscopy alone is not suitable for tumor localization, and other modalities such as DCBE should be applied.

DCBE is widely performed to locate colon lesions; however, CTC is superior to DCBE in several respects. First, CTC clearly demonstrates the involved colonic segment, the length of tumor extension, its relationship with adjacent organs, and vascular structures. Figure 4 shows a cancer's feeding artery, which provides surgeons with information on whether the rest of the feeding artery can be preserved. According to a previous report,[13] the left colic artery (LCA) arose independently from the sigmoid artery in 41% of cases studied, the LCA and the sigmoid artery had a common trunk in 45%, whereas the LCA did not exist in 5%. These vascular variants are not ignorable when we perform laparoscopic surgery. Knowing the relationship of the lesion

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to the feeding artery is especially useful when planning the extent of lymph node dissection. We completed the lymphadenectomy around the inferior mesenteric artery while preserving the LCA in some cases because we were able, through the use of a reconstructed image of the feeding artery as shown in Figure 4, to predict the distance to the branch by CTC.

Second, CTC can be performed simultaneously with the preoperative CT scan without additional X-ray exposure, and patients do not need to be medicated with the additional purgatives required for DCBE. Third, according to a recent randomized trial, the detection rate of colorectal cancer and large polyps was significantly higher in patients assigned to CTC than in those assigned to DCBE.[14]

This study demonstrates the accuracy of CTC images for preoperative T staging. Our results are consistent with the previous report by Horie et al,[15] in which circumferential tumor extent $\geq$ 50% determined by CTC is the criterion for stage T3 or T4.

It has been reported that the detection rates of coexisting polyps increase as the diameter of lesions increases.[16] In our department, we perform colonoscopy just prior to CTC. When colonoscopy finds a polyp larger than 5 mm, we usually remove that endoscopically prior to CTC.[17,18] There were only 16 coexisting polyps left when CTC was performed in this study; with such a small number of polyps, we were unable to evaluate CTC's ability to detect coexisting polyps; further study of this aspect of CTC is needed.

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